CHAPTER 3. HABITAT EVALUATION

Part One: Existing Conditions

The King County River Management Program had decided to seek Endangered Species Act (ESA) coverage for its flood hazard reduction activities under the County's proposed Management Zone 4(d) Rule. The proposed Management Zone model provides that within a specified width on each side of the stream (generally 200 ft on the larger streams and rivers in King County) development activities will be restricted to meet the habitat needs of salmonids. The intent of the proposed Management Zone model is to prevent actions that would worsen existing conditions for salmonids and their habitat, and to preserve future recovery options.

This chapter describes existing conditions including an overall description of the rivers with notes on fish utilization, followed by an assessment of existing stream and riparian habitat conditions (using ESA terminology).

KING COUNTY RIVERS: DESCRIPTIONS WITH NOTES ON FISH UTILIZATION

The rivers of King County are cataloged in four Water Resource Inventory Areas (WRIA) as shown in Figure 3-1. These are:

- **Snohomish Basin (WRIA 07)**. For this report, this includes that portion of the South Fork Skykomish River and its Beckler, Miller, Foss and Tye River tributaries located within King County. That portion of the Snoqualmie River system located in King County, including all three forks plus the Tolt and Raging Rivers, is also cataloged in WRIA 07.

- **Lake Washington Basin (WRIA 08)**. For this analysis, this WRIA is limited to the Cedar River from the Landsburg Dam downstream to the City of Renton.

- **Green/Duwamish Basin (WRIA 09).** This includes the Green River from its headwaters downstream to Tukwila, and thence downstream under the name, Duwamish River, to Elliott Bay.

- **Puyallup Basin (WRIA 10)**. This includes the portion of the White River, and its Greenwater River tributary, that are located within or along the southern border of King County.

For each of these WRIAs, a map illustrating the approximate location of river facilities maintained by King County and the general proximity of clusters of chinook spawning and upper extent of chinook distribution was developed (Folio Maps 1-1 and 4-1 – 4-7). These maps are included to assist the reader in understanding the general characteristics of King County river facilities in relation to fish usage during spawning activity.

South Fork Skykomish River (WRIA 07)

The South Fork Skykomish River is formed by the confluence of the Tye and Foss Rivers approximately 11 miles west of Stevens Pass. The river flows west then northwest across the northeastern corner of King County past the communities of Skykomish and Baring, then on into Snohomish County. Its principal tributaries in King County are the Miller, Beckler, Tye and Foss Rivers plus Money and Index Creeks. Altogether, this system accounts for 454 linear miles of stream in King County (Williams et al. 1975).

The Burlington Northern railroad and US Highway 2 parallel the river through the valley on the north side. Even though these features have been overtopped by floodwaters in the past, they constrain channel migration to the north side of the valley. The principal land uses are forestry and recreation; much of the building development that has occurred is clustered along the river's banks. Significant areas of development in the floodplain include part of the town of Skykomish, the communities of Grotto and Baring, and several scattered residential subdivisions (King County 1993b).

With its source high in the Cascade Mountains, the South Fork Skykomish drops along a fairly steep gradient with high velocity. Runoff from rainstorms and snowmelt is marked by high peak flows of short duration that scour banks and create braided channels in portions of the mainstem (King County 1990). Clay banks along the north bank above RM 67 slough off during such flow events, producing silt and fine sediment that deposits in places along the mainstem (Williams et al. 1975). Past logging practices in the Beckler watershed have exacerbated this problem (Wissmar and Beer 1994).

The King County River Management Program inventory (Table 1-2) shows seven flood and erosion control facilities in the South Fork Skykomish system that total 0.97 linear miles of streambank, the lowest total in the inventory. Four levees contain the South Fork Skykomish River through the town of Skykomish. These provide only modest flood control, however; a flow of 7,700 cubic feet per second (cfs) (a three-year recurrence interval event) reaches the top of these levees. Farther downstream, near RM 57.7 at the mouth of Index Creek, the inventory shows three short rock-faced revetments known as the Dallas, McKnight, and Winkler facilities. Each is a relatively short facility (150-200 feet) evidently intended to protect homes from erosion. Both the Burlington Northern Railroad and the King County Roads Division have constructed other rock revetments in this vicinity to protect the tracks and a County road where they encroach closely on the north bank of the river, but these facilities are not part of the River Management Program.

Historically, none of the King County portion of the South Fork Skykomish drainage supported anadromous fish. In a 2.5 mile reach beginning about two miles downstream from the King County line, the South Fork Skykomish flows over three major falls: Eagle Falls (28-foot drop), Canyon Falls (48-foot drop), and Sunset Falls (88-foot drop). This complex forms a natural barrier to upstream migration that prevented anadromous fish from reaching the King County portion of the drainage until a fishway trap-and-haul facility was constructed at Sunset Falls in the late 1950s. After completion of this facility, anadromous fish were introduced into the upper drainage. Prior to that, the only salmonids in the upper South Fork and its King County tributaries were resident rainbow and cutthroat trout and mountain whitefish (*Prosopium williamsoni*). Historical accounts indicate that the resident rainbow trout in particular were both abundant and robust, with the fish reaching three to six pounds in weight (Piper and Taft 1925).

The South Fork Skykomish system in King County is now used by three ESA-listed or candidate stocks: (1) Bridal Veil Creek fall chinook, (2) South Fork Skykomish coho, and (3) the Skykomish stock of bull trout. Other anadromous fish stocks utilizing portions of this system include one stock each of summer and winter steelhead and an odd-year stock of pink salmon. Resident rainbow and cutthroat trout also persist, but not in the numbers or size range once reported. Mountain whitefish are also still present in the drainage. The South Fork Skykomish mainstem provides a migration corridor along with spawning and rearing habitat for chinook and coho salmon, as well as a migration corridor for bull trout. Chinook and coho also use approximately four miles of lower Money Creek and 1.5 miles of lower Index Creek. Coho use the lower half-mile of Maloney Creek, the lower 0.25 mile of Anthracite Creek, and the lower 0.75 mile of Lowe Creek.

While fall chinook spawn in the Tye River from its junction with the Foss River upstream to Alpine Falls, they concentrate their spawning activity in the two mile section of mainstem channel between RM 71 and RM 73 (SBSRTC 1999). Coho salmon ascend and use this reach as well; these fish also spawn in accessible side channels and small tributaries (Williams et al. 1975; WDFW and WWTIT 1994a; SBSRTC 1999). The reach between RM 4.3 and RM 8 of the East Fork Foss River is of particular significance to bull trout, which home to this reach almost exclusively for spawning (WDFW 1998). To fully occupy this reach, these bull trout traverse a very steep falls-cascade segment at RM 5.2-5.3, as well as another steep cascade at RM 6.9. Both of these cascades were mapped as migration barriers by Williams et al. (1975). Bull trout are capable of ascending such barriers to reach suitable spawning areas, whereas salmon are not (Kraemer 2001).

The Beckler River hosts both chinook and coho salmon up to about RM 11.7 in Snohomish County (Wissmar and Beer 1994). However, the primary area for chinook spawning (i.e., where particularly heavy clusters of spawning redds occur) is from RM 3 to RM 5 in King County, downstream from the mouth of Harlan Creek (SBSRTC 1999). Coho use the

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smaller side channels of the mainstem and all accessible reaches of its small tributaries. Juveniles of both species rear throughout these waters with coho juveniles residing year-around. The Miller River hosts both chinook and coho salmon up to RM 6 in the mainstem and East Fork, and to RM 0.8 in the West Fork. Chinook salmon spawn in main channel reaches primarily downstream of the forks. Coho use the stream's shallow side channels plus accessible tributaries. Juveniles of both species rear throughout these waters with coho juveniles residing year-around.

Snoqualmie River (WRIA 07)

Three major forks converge to form the mainstem Snoqualmie River. The South Fork Snoqualmie River begins near Snoqualmie Pass and flows generally northwest for 35 miles to its confluence with the mainstem upstream of Snoqualmie Falls. The I-90 freeway parallels the South Fork into the mountains. The Middle Fork, which begins in the Mt. Daniel-Mt. Roosevelt-Big Snow Mountain area of the Cascade Mountains, flows west and southwest 40 miles to its confluence with the North Fork about five miles upstream of Snoqualmie Falls. The North Fork originates in the Lennox Mountain area of the high Cascades and flows 26 miles to its confluence with the Middle Fork. The combined Middle and North Forks join the South Fork about 4.5 miles upstream from Snoqualmie Falls. The Snoqualmie River downstream of the forks flows over Snoqualmie Falls, then generally northwest and north, leaving King County just north of the town of Duvall. Important tributaries are Tokul, Skunk, Patterson, Griffin, Harris, Ames and Cherry Creeks and the Tolt and Raging Rivers. Altogether, the three forks of the Snoqualmie and their tributaries plus the mainstem and its tributaries below Snoqualmie Falls account for 817 linear miles of stream in King County.

Perkins (1996) prepared a channel migration study of the three forks area of the Snoqualmie River upstream of Snoqualmie Falls. This information, which provides descriptive details of this area, is incorporated here by reference. Shannon & Wilson (1991) also produced channel migration studies of the Tolt and Raging Rivers that provide descriptive details of those two major tributaries.

In contrast to the Green River valley, which by the late 1970s had already been heavily developed, land use in the Snoqualmie valley downstream of Snoqualmie Falls has been mostly dairy agriculture (Ehrlich 1978). Development pressures, however, have been heavy in recent years. In the lower (north) part of the valley, downstream of Carnation to the King County line, some of this conversion is from dairy to poplar agriculture; zoning density does not prevent conversion to "hobby farms" or to homes on large acreage. The latter types of conversion are more prominent near Carnation and upstream toward Fall City.

The King County River Management Program inventory lists 231 facilities (the largest number for any watershed in the inventory) along 45.7 miles of riverbank both upstream and downstream from Snoqualmie Falls. Working downstream from the falls, a series of six revetments and/or training levees have been constructed to prevent erosion, protect roads or other structures, or to constrain the river in its present course downstream to Fall City. This includes one extremely long facility on the left bank at about RM 37.7. Downstream of Fall City are many more long training levees and revetments that mainly protect against erosion and channel migration, and confine the channel in its present position. Most if not all of the levees are low and only contain high flows of 2-year recurrence interval or less.

The Raging River has a reputation for fast runoff and flash flooding, hence its name. Mean annual flow is 146 cfs; summer low flows are 9 to 15 cfs. Flood control levees have been constructed along the full length of both banks in the lower two miles of the channel near Fall City. In the 1960s, gravel was removed from the mouth of the Raging River as a flood control measure (Shannon & Wilson 1991). Channel migration zones occur from RM 5.8 to 8, and from RM 3.8 downstream to the leveed reach. The principal means of channel migration in this area is lateral migration (Shannon & Wilson 1991). Straightening of bends by cutoffs and short avulsions have occurred from RM 2.8 to 5.8; multiple channels have formed in the reach between RM 4.7 (the I-90 bridge) and 5.8, giving the reach a braided appearance (Shannon & Wilson 1991). The King County River Management Program inventory shows eight scattered revetments that serve as erosion protection for individual parcels of property within these zones.

In the Tolt River, the dominant type of channel migration differs in different reaches (Shannon & Wilson 1991). Lateral migration is dominant from RM 5.9 to 5.0; avulsions and cutoffs appear to be dominate from RM 3.8 to 1.8, which gives this reach a braided appearance. Channel splitting and overflow side-channels occur downstream of RM 3.8, which is the upstream end of a large alluvial deposit known as the Tolt Delta. From about RM 2.0 downstream to the mouth, the Tolt River along both banks is confined between high levees that were built for flood containment. These levees are set back for long stretches near RM 2.0, allowing some degree of channel mobility in this area. These levees cut off connections with side channels, ponds and wetlands except for one location where a culvert maintains connectivity with an off-channel pond. A study of alternatives for levee setbacks and removals to reconnect some of these off-channel habitats is currently underway.

The Snoqualmie River in King County is used by two ESA-listed or candidate stocks: (1) Snohomish fall chinook, and (2) Snoqualmie coho. Bull trout have not been found anywhere in the Snoqualmie system (WDFW 1998). Other anadromous fish stocks utilizing portions of this system include one stock each of summer and winter steelhead, one stock of chum salmon, an odd-year stock of pink salmon, and sea-run cutthroat trout. While not mentioned by the resource management agencies (WDFW and WWTIT 1994 a.), longtime local residents also mention a run of small sockeye salmon that ascended the Snoqualmie River to the vicinity of Fall City (Beardslee 2001). Resident rainbow and cutthroat trout are also present in the drainage; populations of these fish are particularly abundant and robust in the three forks of the river upstream of Snoqualmie Falls (Pfeifer 1985). Because Snoqualmie Falls is a complete natural barrier to upstream migration, anadromous fish use has historically been restricted to the mainstem Snoqualmie and its tributaries downstream of the falls.

Fish use much of the mainstem Snoqualmie River downstream of Snoqualmie Falls as a migration corridor. Major chinook spawning aggregations occur in gravel riffle and channel split areas between RM 22 and 25 downstream of the mouth of the Tolt River, and between RM 34 and 35 downstream of the mouth of the Raging River. Some chinook spawning also occurs in the boulder strewn reach between the mouth of Tokul Creek and Snoqualmie Falls, upstream of RM 39.6. While some coho salmon spawn in the mainstem reaches between RM 22 and 25 and between RM 34 and 35, utilizing the shallower and slower side channels and braids, and in the mainstem reach between Tokul Creek and Snoqualmie Falls, most coho spawning occurs in the tributaries. The reach between the mouth of Tokul Creek and Snoqualmie Falls also appears to be a holding area for a portion of the adult summer steelhead bound for the Tolt River (Beardslee 2001). These fish hold in the Tokul Creek to Snoqualmie Falls reach, then, later in the fall, drop back and ascend the Tolt River where they eventually spawn.

While Chinook salmon spawn and rear in the Raging River up to and beyond RM 7.0, it has been estimated that 85 percent of the spawning takes place in the lower four miles of river downstream of Preston (Williams et al. 1975). Coho salmon inhabit the entire accessible river and tributaries, with a fair number of fish using Lake and Deep Creeks (Williams et al. 1975). Chinook and coho salmon also utilize the Tolt River, as do steelhead, chum and pink salmon (the latter two species in the lower four miles). Coho salmon also use Stossel and Langlois Creeks.

Cedar River (WRIA 08)

Prior to 1916, when the Montlake cut was constructed and the government locks and Lake Washington ship canal were completed, the Cedar River discharged into the Black River, which was also the outlet for the Lake Washington drainage. As part of the ship canal operation, the Cedar River was diverted into Lake Washington and the Black River outlet ceased.

The Cedar River originates in the Cascade Mountains near Stampede Pass and flows west-northwest nearly 50 miles to its present confluence with Lake Washington at Renton. The uppermost 10 miles flow through steep-sloped, narrow, forested mountain terrain in a channel characterized by high gradient riffles and cascades. Two water storage reservoirs, Chester Morris and Cedar Lake, occur in the next nine miles. Downstream from Cedar Lake to the City of Seattle water diversion dam at Landsburg (RM 21), the forested valley is alternately narrow and broad. While the river has many gentle-gradient reaches with good pool-riffle areas, the diversion dam is a total barrier to upstream migration of anadromous fish. The reach between the diversion dam and the Highway 18 bridge at approximately RM 14.6 contains several high gradient boulder areas with only intermittent pool-riffle sequences. This is, however, an area of good gravel recruitment and high use by spawning salmon. The King County River Management Program inventory shows several bank protection revetments along this reach. Rock Creek, a tributary utilized by anadromous fish, enters at RM 18.2.

Downstream of Maple Valley to the SR-169 crossing (approximately RM 13.4 to 11) is becoming heavily residential. Although levees at the upper end of this reach constrain the river and provide some flood protection, all of them overtop. The river meanders over a shallow, relatively broad valley through this reach, taking on a pool-riffle character with good spawning and rearing habitat for fish. Peterson and Downs (a.k.a. Taylor) Creeks, tributaries used by anadromous fish, enter at RM 13.8 and 12.8 respectively.

River mile 11 to 9 is referred to as the Belmondo reach. Here the gradient is moderately steep and the channel splits, even though bedrock along much of the left bank and an old railroad grade parallel to the river are major confining features. While RM 9 to 4.3, where SR-169 crosses again, has a series of revetments and training levees that confine the river, there is still opportunity for the channel to move in the vicinity of Madsen Creek (confluence at RM 4.5). Levees in this reach provide flood protection up to a 25-year event. The lower three miles of the Cedar River is heavily industrialized; downstream of the I-405 crossing (RM 1.6), the stream is channelized through the City of Renton and the Boeing manufacturing complex. The King County River Management Program has no facilities in this lowest reach.

In all, from the Landsburg diversion downstream, the King County River Management Program inventory lists 65 flood and erosion control facilities along 9.9 miles of streambank.

The Cedar River is used by three ESA-listed or candidate species: (1) the Cedar River summer/fall chinook, (2) Cedar River coho, and (3) Chester Morse Lake bull trout. In addition, one stock of winter steelhead, one stock of sockeye salmon, and migratory cutthroat trout also use the stream. Although overall spawner distribution for Cedar River summer/fall chinook extends from RM 2 near Renton to the Landsburg Diversion Dam at RM 21 (WDFW and WWTIT 1994b; Mavros et al. 2000), areas of concentrated chinook spawning are located at RM 6 to 7, RM 10 to 11, and RM 13 to 19 (Mavros et al. 2000). Cedar River coho also use the river from Renton to the Landsburg Diversion (WDFW and WWTIT 1994b). Rock Creek, Downs Creek, and several of the other Cedar River tributaries are also known coho spawning tributaries (Williams et al. 1975).

A reproducing population of bull trout occurs in the upper Cedar River basin in Chester Morse Lake (Connor et al. 1997; Reiser et al. 1997; WDFW 1998). This population exhibits the lacustrine or adfluvial life history. Whether anadromous or fluvial bull trout persist in the Cedar River downstream of the City of Seattle water works is a matter of conjecture. There is an oral history of bull trout using Rock Creek, a Cedar River tributary that enters at RM 18.2 (Burlingame 2000). While bull trout have been captured in Shilshole Bay near the Lake Washington Ship Canal outlet and in Lake Washington itself (Miller and Borton 1980; Pfeifer and Bradbury 1992; WDFW 1998; Footen 2000) there is no evidence confirming that these fish originated in the Cedar River.

Green River (WRIA 09)

This drainage now consists of a single river system, the Green River, which in its lower 11 miles from Tukwila downstream, is also known as the Duwamish River. Formerly, the Green River was a tributary of the White River (confluence about RM 31 at Auburn); the combined flow continued down what was then known as the White River Valley (now the Kent Valley) to join the Black River at Tukwila to form the Duwamish. Diversion of the White River into the Puyallup reduced the flow in the lower 31 stream miles by more than half, and reduced the sediment supply to that portion of the system by about 75 percent (Mullineaux 1970).

The Green River begins in the Cascade Mountains on Blowout Mountain about 30 miles northeast of Mt. Rainier. It flows generally west and northwest for about 25 miles through a mostly narrow, steeply sloped, forested valley before coming to gentler slopes and broader valleys. At RM 68, the stream enters the reservoir behind Howard Hanson Dam, a Corps of Engineers flood control facility completed in 1962. The dam itself is at RM 64.5, and downstream of that, at RM 61, is the City of Tacoma water diversion facility, which represents the present upper limit of anadromous fish migration. The upper drainage, although mostly in Forest Service ownership, is managed as a municipal watershed. Downstream of the water diversion, the gradient remains steep as the river traverses the tightly confined Green River Gorge, emerging at Flaming Geyser Park, approximately RM 46.5. There the valley broadens and the river gradient suddenly moderates, causing deposition of large amounts of gravel. The channel is unstable here and can migrate erratically, taking on a braided character. This physically and hydraulically complex reach is among the most productive remaining mainstem areas for anadromous salmonids in King County (Coccoli 1993). Important tributaries in this reach are Newaukum, Crisp, Burns, and Soos Creeks. While the land use is largely agricultural, conversion to housing tracts is evident in places. Within Auburn, approximately RM 32, the river turns north and enters the broader, flatter valley where it had formerly been part of the White River. Industrial and urban land uses had rapidly replaced former farmland in this valley by as early as the mid 1970s (Ehrlich 1978). The former White River channel at Auburn has been filled in and is covered by housing tracts. Downstream of the former White River confluence at about RM 31, the channel gradient is low, flows are slow, and the river occupies a narrow channel confined within revetments and flood control levees. There are few if any gravel deposits within this lower reach. In addition to the City of Auburn, the City of Kent is also located in this reach.

The King County River Management Program inventory lists 137 flood and erosion control facilities totaling 36 miles of stream bank along the Green River. Revetments and levees impede lateral migration of the Green River in many locations from Flaming Geyser Park (RM 46.5) downstream to Elliott Bay. Revetments and levees are present along at least one bank for just over 50 percent of the river's length from RM 46.5 downstream to RM 25 near Kent, with most of the facilities concentrated in the lower portion of this reach (Perkins 1993). Containment of the channel by King County River Management Program facilities continues downstream to approximately RM 6.6 (the SR-99 bridge), where the City of Tukwila or the U. S. Army Corps of Engineers assumes responsibility. The former Black River confluence is located at RM 11.

Howard Hanson Dam was built by U. S. Army Corps of Engineers in 1962. Outflows from the dam are regulated so that the flow at Auburn will not exceed 12,000 cfs, the equivalent of a two-year recurrence-interval flood prior to construction of the dam (Perkins 1993). The size of the two-year recurrence-interval flood at Auburn today is about 27 percent less than it was prior to construction of the dam (Perkins 1993). Though regulation has reduced magnitude of floods on the river, water stored by the dam during one flood must be released to create storage for the next. As such, the operation of the dam has also increased the duration of moderately high flows, i.e., those between 1,500 and 10,000 cfs (Dunne and Dietrich 1978; Perkins 1993). Since a large proportion of the sediment on the riverbed is mobilized by flows greater than 2,200 cfs, significant amounts of bank erosion can occur within this range of flows. Howard Hanson Dam also traps sediment from about 55 percent of the watershed upstream of Auburn, which has greatly reduced the sediment supply downstream. Alluvial and glacial deposits between Green River Gorge and Auburn continue to supply some coarse sediment to the river, as does Newaukum Creek (Perkins 1993). Soos Creek's sediment load, trapped in low gradient reaches within the creek itself, does not reach the Green River (King County 1989; Perkins 1993). The result of this is that gravels in the Green River streambed give way to sand and silt at about RM 25.5, which marks about the lowest point at which salmon spawning occurs.

The Green River is used by four ESA-listed or candidate species: (1) Duwamish/Green summer/fall chinook, (2) Newaukum Creek summer/fall chinook, (3) Green River/Soos Creek coho, and (4) Newaukum Creek coho. In addition, two stocks of chum salmon, one stock each of summer and winter steelhead, and sea-run cutthroat trout also use the river and its tributaries. According to the historical record, anadromous native charr (either bull trout or Dolly Varden charr) also occurred (Suckley 1859). A putative bull trout specimen was captured by the Muckleshoot Indian Tribe near the mouth of Newaukum Creek in February, 2000; there is ample evidence from captures that anadromous bull trout regularly use the lower Duwamish River downstream of RM 5.8, especially in the spring. These fish are believed to be migratory visitors from other watersheds that entered the Duwamish perhaps to forage on outmigrating smolts (King County 2001). No bull trout have been found in recent surveys of the upper basin upstream of Howard Hanson Dam and no bull trout stock is presently recognized as existing in the Green River by WDFW (1998). While odd-year runs of pink salmon once used the Green/Duwamish basin, these stocks have been extinct since the mid-1930s (Williams et al. 1975). The system is also used by resident stocks of rainbow and cutthroat trout and by whitefish. The City of Tacoma water diversion facility represents the present upper limit of anadromous fish migration in the system. Some returning adult fish are trapped downstream of this facility and released upstream of Howard Hanson Dam in an attempt to reintroduce salmon and steelhead into the upper watershed.

The lower Green River up to RM 25.5 is used primarily as a migration corridor for adult salmonids moving to upstream spawning areas, and for downstream migrating smolts. Coho salmon also enter the old Black River system (confluence at RM 11) and spawn and rear in its tributary, Springbrook Creek (Williams et al. 1975). Coho salmon also utilize Mill (a.k.a. Hill) Creek and Mullen Slough (confluence with Green River at RM 23.9) for spawning and rearing (Williams et al. 1975). Juvenile chinook have also been found in the lower reaches of Mill Creek and nearby Mullen Slough. Mainstem spawning principally by chinook salmon but also by coho salmon takes place upstream of RM 25.5. The channel here is more mobile and hydraulically complex and suitable gravel deposits can be found, with a concentration of chinook spawning occurring between RM 29 and 30.5. Mill Creek (east of Kent) and Soos Creek (east of Auburn) are used for spawning and rearing by coho salmon. Chinook salmon also use the lower six miles of Soos Creek for spawning. Newaukum Creek has its own recognized stocks of chinook and coho salmon. Chinook spawning is limited to the lower 10 miles; coho ascend into all accessible tributaries.

White River (WRIA 10)

Prior to 1906, the White River flowed through Auburn where it was joined by the Green River. From there it flowed through what was then called the White River Valley (now the Kent Valley) to its confluence with the Black River, the outlet of Lake Washington, near present-day Tukwila. From there the combined flow, known as the Duwamish River, flowed north to Elliott Bay. In 1906, a flood-deposited debris jam formed at Auburn, diverting the White River south down an old overflow channel known as the Stuck River, into the Puyallup River in Pierce County. In 1915, a year or so before the government locks and Lake Washington ship canal were completed, this diversion was made permanent by construction of what is now referred to as the "Auburn Wall." A portion of the White River upstream from Auburn still lies entirely in King County, and much of the upper river, from RM 12.4 to the confluence of the Greenwater River at RM 45.8, forms the southern boundary of the county. The county boundary then continues east along the Greenwater River to the Cascade crest.

The White River, which originates from Emmons Glacier on the northeast face of Mt. Rainier, flows north more than 25 miles through eastern Pierce County to the town of Greenwater, where it is joined by the Greenwater River, a major tributary, at RM 45.8. The upper White River is a swift moving, glacial stream that carries a heavy load of sediment in a very dynamic channel. The river substrate consists of boulders, cobble, and large gravel. Near the community of Greenwater, revetments have been constructed to protect property, and a floodwall for flood protection.

Downstream of the community of Greenwater, the White River turns west and follows a meandering course. The channel gradient is about one percent with many channel splits, braids, and deep-cut banks. The Clearwater River, another major tributary, originates on Bear Head Mountain in Pierce County and flows north for 10.5 miles to join the White River at RM 35.3. Mud Mountain Dam, a flood control facility built by the U.S. Army Corps of

Engineers in the 1940's, is at RM 29.6. The upper end of the reservoir behind Mud Mountain Dam, when full, extends upstream past the mouth of the Clearwater River to approximately RM 35.5. Logging and recreation are the principal land uses in this reach along with some gravel mining for road construction. There are no King County River Management Program facilities in this reach.

From Mud Mountain Dam downstream to the mouth of Red Creek at RM 27.5, the river channel is confined in a narrow, steep-sided canyon. The valley then broadens. The substrate consists of boulders, cobble, gravel, and considerable amounts of silt. Gravel riffles are located within the channel splits where channel migration has occurred. Puget Sound Energy's Buckley diversion dam at RM 24.3, which is a complete barrier to fish passage, routes up to 2000 cfs White River water into Lake Tapps. Fish are trapped at this structure for transport upstream of Mud Mountain Dam. Boise Creek (confluence at RM 23.3) is a principal King County tributary in this reach. Boise Creek originates in the Cascade foothills upstream of a former Weyerhaeuser Company sawmill complex. While agriculture is the principal land use, there is a growing trend toward residential housing. The towns of Enumclaw and Buckley adjoin this reach.

From the PSE diversion, the much-reduced White River meanders northwest toward Auburn. The Muckleshoot Indian Reservation straddles the river from RM 15.5 to 8.9. At RM 8.0, the "Auburn Wall" turns the river south down the old Stuck River channel to its present confluence with the Puyallup River in Pierce County. Water from Lake Tapps returns to the river at Dieringer, RM 3.5, in Pierce County. In this so-called "bypass reach," the valley averages about one mile in width with steep hillsides to about 400 ft. elevation. The channel carries a heavy sediment load and considerable channel splitting occurs. Except within the Muckleshoot Indian Reservation, where damaged levees and revetments have not been repaired or replaced, allowing the channel to migrate, the bypass reach is highly channelized and leveed, especially downstream of RM 8.9, where it flows through the Cities of Auburn and Pacific.

In all, the King County River Management Program inventory lists 18 erosion and flood control facilities along 6.8 miles of stream bank in the White River system.

The White River is used by four stocks of ESA-listed or candidate species: (1) White River spring chinook, (2) White River summer/fall chinook, (3) White River coho, and (4) White River bull trout. In addition, one stock of winter steelhead uses the system as do resident cutthroat and rainbow trout in the upper reaches. Some summer/fall chinook spawn in the "bypass reach" between Dieringer (RM 3.5) and the Buckley diversion (RM 24.3). Other summer/fall chinook are captured at the diversion and released upstream of Mud Mountain Dam. Spring chinook, coho, and bull trout normally travel through the "bypass reach" to the diversion, where they are trapped and hauled upstream. However, some coho spawn in Bowman Creek, a King County tributary that enters the White River at RM 7.7, as well as in Jovita and Strawberry Creeks, which are tributaries in the Pierce County reach of the stream. Fish that are trapped and hauled at the Buckley diversion are released near the community of Greenwater, from where they disperse both upstream and downstream. In addition to spawning in the White River itself, spring chinook ascend eight miles of the Greenwater River to Burns Creek (RM 8.2) or a bit beyond, and the lower five miles of the Clearwater River in Pierce County. Coho also use the Greenwater and Clearwater Rivers, as well as the accessible reaches of the small tributaries. Juvenile spring chinook and coho rear in these waters year around.

The Greenwater River originates in a high valley on Castle Mountain north of Naches Pass and then flows generally northwest for 21 miles to its confluence with the White River. Approximately the upper one-third of the watershed is in the Norse Peak Wilderness administered by the U. S. Forest Service. The stream drops rapidly from its headwaters through a steep, narrow, V-shaped valley, over numerous cascades and a predominately bedrock and boulder stream bottom. Downstream of Burns Creek (confluence at Greenwater RM 8.2), the gradient decreases, the valley alternately widens and narrows, and the channel takes a more meandering course with occasional channel splits and braided reaches. In its lower four miles, the valley is relatively broad and flat. In 1975, the channel from Burns Creek to the mouth was described as having a good pool-riffle ratio with generally stable stream banks consisting of earth or rock cuts or gravel-cobble beaches (Williams et al. 1975). A recent U. S. Forest Service watershed analysis describes the channel and riparian conditions as being severely degraded and disturbed, largely as a result of the heavy logging (USFS 1996). Both the U. S. Forest Service and the State Department of Ecology have identified the Greenwater River as being in "unacceptable" condition and not protecting beneficial uses as required by the Clean Water Act (USFS 1996; WDOE 1998). While commercial forestry is the principal land use, the area also receives fairly heavy recreational use. The only populated area is near the community of Greenwater, near the confluence with the mainstem White River.

Spring chinook and coho salmon utilize the Greenwater River, and it is presumed that bull trout could use the stream as well. This is one of the principal spawning streams for White River spring chinook, with adults ascending as far as Burns Creek (RM 8.2) or a bit beyond (Williams et al. 1975). Coho use both the mainstem and accessible tributaries for spawning. Juvenile spring chinook and coho salmon rear in these waters the year around.

EVALUATION OF EXISTING HABITAT CONDITIONS USING FEDERAL HABITAT EVALUATION GUIDELINES

Both the National Marine Fisheries Service (NMFS) and the U. S. Fish and Wildlife Service (USFWS) have issued guidelines for evaluating the condition of important habitat parameters affecting ESA-listed, proposed, and candidate salmonids. These guidelines are found in the following documents:

- *Making Endangered Species Act determinations of effect for individual or grouped actions at the wastershed scale* (NMFS 1996);
- *A guide to biological assessments* (NMFS 1999);
- *A framework to assist in making Endangered Species Act determinations of effect for individual and grouped actions at the bull trout subpopulation watershed scale* (USFWS 1998).

These guidelines specify the use of a *Matrix of Pathways and Indicators* (Appendix F) to summarize the condition of each of six significant pathways: (1) Water Quality, (2) Habitat Access, (3) Habitat Elements, (4) Channel Condition and Dynamics, (5) Flow/Hydrology, and (6) Watershed Conditions. These six pathways are further divided into indicators. For example, the Water Quality pathway has three indicators: Temperature, Sediment, and Chemical Contaminants/Nutrients. Each of the other pathways has a unique array of indicators. The matrix consists of three columns, one for each of three possible condition for each indicator: (1) Properly Functioning, (2) At Risk, or (3) Not Properly Functioning. These are intended to describe the environmental baseline of the area or site where a proposed action is intended to take place. For each indicator, NMFS or USFWS provides either a numeric value or range, or, where quantitative information is lacking, a narrative description of the appropriate level of condition for that indicator.

This matrix was developed for use in writing Biological Assessments for Section 7 and 10 consultations under the Endangered Species Act (ESA). It is incorporated here to express the current state of habitat in ESA terminology within the King County River Management Program river corridor areas. There is one important caveat: many of the NMFS and USFWS guidelines were developed for moderate gradient streams in forested watersheds where logging is the principal land use. Application of the matrix to the rivers covered here—which are, for the most part, low gradient systems in agricultural, suburban, urban, and industrialized settings—must be tempered with professional judgment. The authors have exercised their own professional judgment in the narrative below. The following discussion explains the rationale used in scoring each indicator.

Environmental Pathways and Indicators—Water Quality

Temperature. Generally, water temperatures in the range of 3° to 20° C (38° to 68° F) are acceptable to adult fish during their upstream spawning migrations. Because most anadromous stocks have evolved with the temperature patterns of their home streams, significant abrupt deviations from normal patterns can stop migration and adversely effect fish survival (Bell 1986; Bjornn and Reiser 1991). High temperatures increase the metabolic rates of fish and result in greater expenditures of energy. While lethal levels for adult salmonids vary, they are generally in the range of 23^{O} to 29^{O} C (73^{O} to 84^{O} F) (Bjornn and Reiser 1991; Caldwell 1994).

Water temperature is also important for spawning. Each stock appears to have a unique time and temperature for spawning that maximizes the survival of offspring in its particular setting. In the case of fall spawning fish, for example, newly spawned embryos must reach a critical stage of development before the water becomes too cold. Fry emergence must also occur at a suitable time the following spring. For spring spawning fish, spawning must not occur before the water has warmed sufficiently for normal development of the embryos. If the temperature suddenly drops, spawning activity may cease. During incubation, water temperature affects the rate of embryo and alevin development and the solubility of oxygen in water (the higher the temperature, the lower the concentration of oxygen). While embryos may survive when oxygen levels decrease below saturation, development is retarded.

Water temperatures also influence the summer rearing of juvenile salmonids. Summer temperatures may exceed physiological stress threshholds, and, occasionally, may reach lethal levels. To cope with high temperatures, salmonids may temporarily use cool-water refuges typically associated with groundwater inputs, subgravel streamflow, or the mouths of cool tributaries.

Except for the Green and White Rivers, there is little information about water temperature ranges or variations for King County rivers. For the Green River, there is ample evidence that temperature is Not Properly Functioning during much of late summer (King County 2001). Water temperatures in the lower Green frequently exceed the temperature criteria for Class A waters set forth in the State water quality standards (Chapter173-201A WAC), and sometimes reach the upper lethal range for salmonids (Grette and Salo 1986; Fishery Sciences, Inc. 1984; Caldwell 1994; King County 2001). Although the upper Green River is not listed on the 1998 Washington State 303(d) list for temperature violations, water temperatures of inflow to Howard Hanson Dam generally exceed the Class AA standard of 16^{O} C (60.8^{o}F) at some period in most years (USACE 1998). This, coupled with high summer temperatures recorded in the lower river, indicates that temperatures in excess of the preferred range for salmonid spawning and rearing is a widespread problem within the Green River. These temperatures could delay upstream migration of adult fish not only within the action area, but far upstream as well.

Caldwell (1994) reported that in August 1992, the cumulative total hours during which water temperature exceeded the State water quality standard ranged from 383 hours at RM 41.5 to 1140 hours at RM 13 on the Green River. A temperature assessment of the White River in 1996 indicated that exceedance of standard occurred 46 percent of the days between July 15 to August 15 at RM 43.4 on the mainstem, and 71 percent of the days in the Greenwater River at RM 1.2 (Kerwin 1999).

The main reasons for these observed temperatures appear to be exacerbation of natural summer low flow conditions by surface and ground water withdrawals within the basin, and the lack of shading of tributary streams and the mainstem for both the Green and White Rivers (Kerwin 1999; Kerwin and Nelson 2000). This extreme lack of shading adjacent to the channel is especially prominent along the lower Green River. Vegetation is absent along the lower Green River due to agricultural activities, construction of roads (including flood control facility access roads) at the top of the bank along miles of river, and residential and commercial development. Along many miles of bankline, establishment of mature stands of native riparian vegetation is impeded by the oversteepened bank slopes that are subject to toe and bank sloughing. The only species that seem to persist under such conditions are herbaceous plants such as reed canarygrass and blackberries, whose presence greatly inhibits establishment of trees and shrubs even if adequate toe support existed. Finally, on both non-federal and federal levees enrolled in U. S. Army Corps of Engineers (USACE) levee maintenance programs, establishment of trees or shrubs in excess of four inches diameter breast height (dbh) is prohibited within slope areas intersecting with the levee prism. Even though King County plants native riparian shrubs during its flood control facility repair projects, levee plantings are still subject to USACE maintenance requirements that may require periodic removal of this vegetation (King County 2001). The River Management Program has not maintained most of these levees to USACE standards due to concern about impacts to riparian habitat.

Although temperature information is lacking for the remaining King County rivers, the Snoqualmie and Cedar Rivers were rated At Risk for this indicator because, in the Snoqualmie, vegetation is absent along much of bank line because of agricultural activities and maintenance of flood control facilities, and the Cedar, because of the immature condition of riparian corridors that makes it less than fully functional to provide shading. Only the South Fork Skykomish River appears to be Properly Functioning for temperature.

Table 3-1.
Summary, Water Temperature Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar		X	
Snoqualmie		X	
S. Fork Skykomish	X		

0308 BEA T3-1.eps LPRE

Sediment/turbidity. A cautionary note about the distinction between turbidity and suspended sediment: turbidity is an optical property of water that results in a loss of light transmission due to absorption or scattering by suspended particles. Colloidal color, plankton, and organic detritus as well as suspended fine sediment (clay and/or sand) can contribute to turbidity (Waters 1995). Turbidity is most commonly measured in the field with a nephelometer and expressed in nephelometric turbidity units (NTU). Suspended sediment is measured as the weight of suspended fine particles (clay and/or sand) carried by the water and is expressed as mg/L or ppm (one milligram per liter is equivalent to one part per million), and the analysis is usually preformed in the lab. While suspended sediment contributes to turbidity, and sometimes turbidity measurements are used as surrogates for suspended sediment measurements, the two are not strictly the same. Very turbid waters with values of 5 to 25 NTU may translate to only about 3-7 mg/L of suspended sediment (Lloyd 1987).

Although, under storm conditions, suspended sediment concentrations in streams can reach levels of thousands of mg/L (Waters 1995), only rarely do they reach the extreme concentrations which laboratory studies have shown can cause direct mortality of salmonids (Noggle 1978). Therefore, much of the concern about suspended sediment and turbidity revolves around sublethal effects.

The following sublethal effects are reported in the literature. During upstream migration to spawning areas, adult salmonids may cease to migrate in waters with high suspended sediment loads (Cordone and Kelley 1961; Bell 1986). In addition to the sediment load *per se*, turbid water also absorbs more radiation than clear water and thus may promote a thermal barrier to migration (Reiser and Bjornn 1979). During construction of spawning redds, fine sediments and organic matter within the substrate are swept out and washed away downstream, leaving the redd environment as favorable for the embryos immediately after construction as it will ever be. However, subsequent depositions of fine sediment may reduce permeability to the point of impairing embryo survival.

As for juvenile salmonids rearing in streams, Noggle (1978) demonstrated that the tolerance of juvenile coho salmon to suspended sediment varies seasonally. The highest tolerance develops in the fall when increased suspended sediment concentrations normally occur in streams with the onset of fall rains. Bisson and Bilby (1982) showed that groups of coho salmon acclimated to clear (>0.3 NTU) and turbid (2-15 NTU) waters in summer exhibited strong avoidance behavior when exposed to later pulses of suspended sediment in excess of 70 NTU and 100 NTU respectively. Conversely, Redding et al. (1980) found that while high levels of suspended sediment (2,000 to 3,000 mg/L) produced an initial mild stress response in juvenile coho salmon and steelhead trout, the fish adapted quickly. Earlier studies by Stuehrenberg (1975) and Klamt (1976) on summer and winter rearing habitat of juvenile steelhead and chinook salmon in Idaho also found that juveniles of both species appeared to tolerate suspended sediment, showing no significant differences in fish density in streams with substrates ranging from 26 to 52 percent fine sediment. Sublethal effects of chronic suspended sediment on steelhead trout and coho salmon fry found in other studies include reduced growth rate (Sigler et al. 1984) and reduced competitive ability of smaller fry against their larger cohorts (Sigler and Bjornn 1980). Noggle (1978) found that the ability of coho salmon fingerlings to capture prey organisms was lost at suspended sediment concentrations of 300 to 400 mg/L.

On the Green River, operation of Howard Hanson Dam has altered sediment transport and profoundly changed the hydrology of the lower river. The City of Seattle waterworks, although not a flood control operation, has likewise had a profound effect on the hydrology of the Cedar River. In the Green River, floodwaters are released from Howard Hanson Dam over a much longer period of time following floods than under historic hydrologic conditions, resulting in the transport of high volumes of silt and sand-sized sediments during moderate and high levels of discharge from the dam. These materials contribute to a significant bedload of finer particles that deposit on the bed of the lower river, and also on midslope benches within channelized reaches. These midslope bench deposits of fine sands and silts contribute to oversteepening of lower embankment slopes and chronic, episodic slumping. One result of this lower bank instability is the pervasive absence of woody vegetation even in areas where no devegetation or riprap placement has occurred for the past 20 or more years. Rooting of woody plants cannot occur rapidly enough to keep pace with the chronic sloughing of these unstable fine-grained lower embankment soils. The net result is a continuing remobilization of fine sediments into the water column throughout the River Management Program action area on the Green River, and corresponding high levels of turbidity during most of the year except for the summer low flow periods (King County 2001).

Given the nature of the fine-grained sediments ubiquitously present throughout the project areas addressed by this report, it is not surprising that episodes of elevated suspended sediment transport and turbidity are frequently present. On the lower Green River, for example, it is not possible to walk on the riverbed, let alone operate heavy equipment along the bank during mid-summer low flow conditions, without mobilizing fine-grained sediments from the streambed into the water column. Because the low flows normally present at these times of year are just marginally below the depositional threshold for such sediments, they tend to settle out quickly, within a few hundred feet of the sediment mobilization zone (King County 2001).

Water quality sampling conducted in 1992 in the lower Green River showed baseflow turbidity at an average level of 5 NTU over many locations (Caldwell 1994). Turbidity in the lower and middle Green River is generally not limiting to fish (King County 2001). To put this in perspective, chinook and coho salmon and bull trout in the glacial White River persist in spite of vastly higher and more prolonged suspended sediment loads during the late spring and summer than are ever likely to occur in other King County rivers. Studies of the aftermath of volcanic impacts such as the 1980 Mount St. Helens eruption, also indicate that salmonids and other aquatic species such as macroinvertebrates are capable of rebounding from turbidity impacts that are even more severe (Lucas 1986).

With regard to what might be considered Proper Functioning Condition for sediment/turbidity in King County rivers, it is important to note that the streambeds of low-gradient, palustrine river channels (the lower Snoqualmie and Green rivers for example) are typically composed of fine sediments such as sand, silt, and pea gravel. Any fine sediments released within the action area, as well as the much larger volumes of sediment from upstream sources such as landslides and forest practices typically settle in these low-gradient channel reaches. Base on these considerations, all King County rivers were ranked as At Risk for this indicator.

Table 3-2.
Summary, Sediment/Turbidity Indicator

River	*Properly Functioning*	*At Risk*	*Not Properly Functioning*
Green		X	
White		X	
Cedar		X	
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-2.eps LPRE

Chemical contaminants/nutrients. Properly functioning riverine ecosystems do not exhibit chemical contamination and are generally characterized by low to moderate levels of nutrients. High levels of chemical contaminants such as metals, hydrocarbons and pesticides reduce egg and alevin survival and are toxic to juvenile and adult salmonids. Even low concentrations of such substances can induce physiological stress in fish, alter primary and secondary production of streams, and reduce biodiversity (Seiler 1989, Karr 1991, Nelson et al.1991, Norris et al. 1991). Non-ionized ammonia is toxic to eggs and juveniles of salmonid fishes at high concentrations (Triska et al. 1984; Gregory et al. 1989; Bisson et al. 1992).

All King County rivers within the purview of the King County River Management Program receive inputs of numerous nonpoint sources of chemical contamination and nutrients, including stormwater runoff from urbanized landscapes and logging road networks, nutrients (especially phosphorus and nitrogen) from agricultural areas, lawns and golf courses, and fine sediment from runoff from logged upper watershed catchments. Fine soil particles also enter the rivers from slumping and eroded riverbank surfaces. As a result, all King County rivers from the most heavily developed Green River to the least developed South Fork Skykomish, were ranked as At Risk for this indicator.

Table 3-3.
Summary, Chemical Contaminants/ Nutrients Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green		X	
White		X	
Cedar		X	
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-3.eps LPRE

Environmental Pathways and Indicators—Habitat Access

Physical barriers. The usual application of this indicator is in regard to anthropogenic blockages to fish migration such as dams, screens, flap gates or water diversion structures in the mainstems or important tributaries. Migration impairing or blocking culverts in tributaries are also included in this indicator. The Tolt, Cedar, Green, and White Rivers each have man-made blockages to fish passage in their main channels: the Tolt at the City of Seattle water supply dam, the Cedar at the City of Seattle water diversion at Landsburg; the Green River at the City of Tacoma diversion dam; and the White River at the Buckley diversion dam. A fish trap-and-haul operation at Buckley provides access for anadromous fish to the upper White River, and trap-and-haul trials continue to re-introduce anadromous fish to the upper Green River. The Cedar River remains blocked at Landsburg. In addition, at least one flap gate that blocks access to an unnamed coho spawning tributary has been identified on the lower Green River (King County 2001).

Another important aspect of this indicator in larger river systems is access to off-channel habitats that could be used for juvenile rearing. Perhaps more than any other salmonid species, juvenile coho salmon utilize off-channel ponds and wetlands, side channels, back channels, and springbrooks during the overwintering period of their life cycle (Sandercock 1991). Studies of survival of juvenile coho rearing in off-channel areas indicate that survival is enhanced by access to such habitats (Bustard and Narver 1975; Peterson 1982; Tschaplinski and Hartman 1983; Brown and Hartman 1988; Swales et al. 1988; Solazzi et al. 2000). Side channels, braided or anastomosed reaches, and back channels may also provide important rearing habitat for juvenile chinook salmon during their tenure in streams (Healey 1991). Although bull trout are suspected to spawn to some extent in ground-water-fed areas, studies to date have not revealed the use of off-channel habitat by this species (McPhail and Baxter 1996).

Access to critical habitats has often been eliminated as a result of flood and erosion control projects (Perkins 1993, 1996; Dillon et al. 1998). Therefore, it is safe to say that most King County rivers in the programmatic action area are Not Properly Functioning for this aspect of the habitat access indicator. The South Fork Skykomish River is ranked as At Risk. While this river is in a naturally confined valley with a much narrower floodplain and fewer off-channel habitats compared with the other King County rivers, a highway, a railroad and a small number of flood and erosion control facilities have altered access to the floodplain.

Not all rearing fish habitat values are lost when flood and erosion control projects are constructed. While riprap areas are used by juvenile salmonids to some extent (Dillon et al. 1998), different methods of bank stabilization influence fish abundance differently (Li et al. 1984; Knudsen and Dilley 1987; Lister et al. 1993; Beamer and Henderson 1998; Peters et al. 1998). Overall, the loss of critical off-channel habitats for overwintering coho juveniles, and the loss of back channels and the side channels that occur in braided and anastomosed reaches that are important for early rearing of juvenile chinook in streams, overrides the modest amount of habitat provided by riprap (Dillon et al. 1998).

Table 3-4.
Summary, Physical Barriers Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar			X
Snoqualmie			X
S. Fork Skykomish		X	

0308 BEA T3-4.eps LPRE

Environmental Pathways and Indicators—Habitat Elements

Substrate. In properly functioning river systems, sediment and its transport from its source to downstream reaches is an important process that affects and maintains salmonid habitat. Suitably sized, clean gravel provides a quality substrate for salmon egg incubation, food source production and cover from predators. Sediment recruitment and transport that is disrupted or perturbed by impoundments, channel diversions, mass wasting and pervasive bank erosion, results in degraded fish habitat. Chronic bank erosion of fine sediments and their instream deposition can reduce egg and alevin survival, reduce primary and secondary productivity, and interfere with feeding, behavioral avoidance and social organization (Bisson and Bilby 1982; Berg and Northcote 1985; Everest et al. 1987; Chapman 1988). Sediment from mass failures and landslides can result in these same effects, as well as filling pools and induce channel migration (Beschta 1978; Cederholm et al. 1981; Everest et al. 1987; Swanson et al., 1987, Chapman, 1988).

Substrate is ranked as Not Properly Functioning for all salmonid species in the Green River. The historic diversion of the sediment-rich White River reduced the sediment supply to the lower Green River by 75 percent (Mullineaux 1970), and the Howard Hanson Dam impounds between 6,500 and 19, 700 tons of gravel per year that was formerly routed from the upper Green River to downstream areas (USACE, 1998). As a result, gravel within downstream reaches to at least RM 58.0 (the upstream end of the Flaming Geyser Gorge) that is mobilized by moderate to large flood events is not replenished by transport from upstream reaches. Spawning and rearing habitat has decreased in quantity and quality compared to historic levels; diversion of the White River has essentially ensured that such gravels cannot be fully replenished.

In the other King County rivers, the rankings are more arbitrary and rely on the authors' professional judgement because of a lack of quantitative information. The substrate in the White and Cedar Rivers is ranked as At Risk because of the presence of a flood control structure in the White River and water withdrawal structures in both rivers that interrupt sediment transport. Sediment routing and substrate in the Snoqualmie and South Fork Skykomish Rivers appear to be Properly Functioning.

Table 3-5.
Summary, Substrate Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar		X	
Snoqualmie	X		
S. Fork Skykomish	X		

0308 BEA T3-5.eps LPRE

Large woody debris (LWD). Instream LWD is a critical component of salmonid habitat (Swanson and Leinkaemper 1978; Bryant 1983; Harmon et al. 1986; Gregory et al., 1991; Peters et al. 1998; Bilby and Bisson 1998). NMFS (1996) considers 80 pieces per mile to be the minimum for a Properly Functioning Condition rating.

Against this standard, a recent survey of the middle Green River between the SR-18 and SR-169 bridges found just 29.6 pieces of LWD per mile and three logjams (Fuerstenberg et al. 1996). Another survey of LWD between RM 5 and RM 11 found only 9.5 pieces per mile, not counting the pieces deliberately introduced in association with bank stabilization projects (Pentec 1999). The small amount of LWD that exists in the programmatic action area of the Green River is widely scattered single deciduous logs and relatively old, decayed, deeply embedded, coniferous pieces. Up to 80 percent of the riverbanks below SR-18 have been modified, with attendant removal of LWD sources (Fuerstenberg et al. 1996). Because of the lack of LWD further upstream in the system, and the pervasive lack of riparian forests along the lower Green River, current recruitment of LWD into the lower river is negligible (Fuerstenberg et al. 1996). Therefore, the Green River is ranked as Not Properly Functioning for the LWD indicator.

Although not a quantitative survey, a 1992 assessment of the Cedar River noted that this channel too is low in LWD. This condition was attributed to alterations that have occurred over time to change the rivers's riparian corridor from a conifer-based, structurally complex forest to one dominated by deciduous trees with only a few immature conifer stands (PSCRBT 1992). Even though the riparian corridors along the Cedar River downstream of Landsburg are reasonably intact, their deciduous dominance and immature condition do not provide significant possible recruitment of LWD to the stream channel at present (King County SWM 1993a).

The authors are not aware of any other information about LWD for other rivers within the King County River Management Program programmatic action area. However, owing to the lack of vegetative cover along much of its riparian area that has reduced the natural recruitment of new LWD to the channel, the Snoqualmie River can also be considered Not Properly Functioning for LWD. While the other King County rivers would score better, they would, nevertheless, be considered At Risk for this indicator.

Table 3-6.
Summary, Large Wood Debris Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie			X
S. Fork Skykomish		X	

0308 BEA T3-6.eps LPRE

Pool frequency. Only one detailed pool inventory of a river within the King County River Management Program programmatic action area was found. In the Cedar River downstream of Landsburg, there was an average of only 2.8 large pools per mile [a large pool is defined as one equal to or greater than 1 channel width in length] (King County 1993a). This is Not Properly Functioning according to the NMFS and USFWS guidelines, which specifies an average of 18 large pools per mile for the Properly Functioning condition. In the lower Green River, King County (2001) also considers pool frequency to be Not Properly Functioning because natural elements such as LWD that contribute to the formation and maintenance of deep, structurally complex pools are largely absent because of human-caused alterations. Boulders and bedrock, which also form pools in steeper gradient streams, are not naturally present in the lower Green River.

As with the LWD indicator, the other King County rivers would likely score better for pool frequency than either the Cedar River or the heavily development-impacted Green River. Even so, they would probably be considered At Risk for this indicator.

Table 3-7.
Summary, Pool Frequency Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-7.eps LPRE

Pool quality. As with pool frequency, Fuerstenberg et al. (1996) and King County (2001) cite extensive changes in the mainstem Green River channel and throughout the valley floor as having drastically reduced pool quality compared to predevelopment conditions. King County (1993a) considers the same of the Cedar River downstream of Landsburg. Prior to these alterations, abundant well-shaded pools existed in both rivers where adult salmonids held prior to moving to upstream spawning grounds. Rearing juvenile salmonids would have been seasonally present in high numbers in such pools in the lower river and the downstream portions of its tributaries. Although spawning and rearing still occur in the Cedar River (Mavros et al. 2000), most of the Green River in the programmatic action area presently consists of transportation habitat that is grossly deficient in high quality juvenile salmonid rearing areas and adult resting pools.

As with the LWD and pool frequency indicators above, other King County rivers would likely score better for pool quality than either the Cedar River or the heavily development-impacted Green River. Nevertheless, they should be considered At Risk for this indicator within programmatic action areas.

Table 3-8.
Summary, Pool Quality Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-8.eps LPRE

Off-channel habitat. The importance of off-channel habitat has been discussed in several places in this report. Off-channel habitat is ranked Not Properly Functioning within the programmatic action areas along the Green, White, Cedar and Snoqualmie Rivers because of extensive channelization, bank hardening by flood and erosion control facilities, and the filling and conversion of off channel habitats for other developed land uses. An inventory of off-channel habitats conducted along the Cedar River by King County in 1992 revealed a network of 68 such habitats still in existence between Landsburg and Renton (King County 1993a), with only nine completely inaccessible to fish due to the reasons cited above. However, of the still-connected habitats, 37 sites were rated poor as salmon habitat because of poor habitat conditions within their own channels and riparian zones resulting from the encroachment of developed land uses (King County 1993a). While the South Fork Skykomish River, with only 1.1 mile of flood and erosion control facilities along its length, is most likely to be Properly Functioning, it was ranked At Risk for the off-channel habitat indicator because of the presence of even these few bank hardening facilities.

Table 3-9.
Summary, Off-channel Habitat Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar			X
Snoqualmie			X
S. Fork Skykomish		X	

0308 BEA T3-9.eps LPRE

Refugia. Refugia are habitats or environmental factors that convey spatial and temporal resistance and resilience to biotic communities impacted by biophysical disturbances (Sedell et al. 1990). Mainstem pools can offer thermal refugia for migrating adult chinook and other salmonids (Berman and Quinn 1991; Fresh et al. 1999). The Green River within the programmatic action area is currently considered Not Properly Functioning for this indicator because riparian reserves and off-channel habitats are either highly disturbed or entirely absent and mainstem pools are few (Fuerstenberg et al 1996; King County 2001). Mainstem pools are also deficient in the Cedar River, as discussed above under the Pool Frequency and Pool Quality indicators. Data are lacking for other King County rivers. We believe these would score higher, but, because of various human intrusions would, nevertheless, probably be considered At Risk overall for this indicator.

Table 3-10.
Summary, Refugia Indicator

River	*Properly Functioning*	*At Risk*	*Not Properly Functioning*
Green			X
White		X	
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-10.eps LPRE

Environmental Pathways and Indicators—Channel Condition and Dynamics

Width/depth ratio. The numeric criterion of <10 established by NMFS (1996) for this indicator to be in Proper Functioning Condition is clearly appears inaccurate for large, low-gradient alluvial streams such as the lower Green River and lower Snoqualmie. Well-functioning riverine habitats in low-gradient alluvial reaches such as these likely had much higher width/depth ratios in pre-development times. Evidence for this can be seen in the following description of the Green River valley:

"Prior to 1906, the larger portion [of the river] flowed closely along the north side of the valley for two miles, when it turned sharply to the north. After flowing north for about a mile, during normal runoff it was divided into two or three channels but in flood time it was divided into a multitude of channels. These channels seemed to wander aimlessly over the valley …" (Thomas and Thompson 1936).

The historic diversions of the White and Cedar/Black Rivers as well as the gross channel alterations to the lower Green River have confined that channel, affectively narrowing width/depth ratio to <10 within the programmatic action area (King County 2001). The Cedar River channel has likewise been narrowed via diversions for municipal water withdraws and then confinement by flood and erosion control structures (King County 1993a). The lower portions of the Tolt and Raging Rivers have likewise been confined and altered by control structures. Thus, while the channel forms of these rivers may be technically in accordance with NMFS (1996) criteria, this does not indicate Proper Functioning Condition, but rather, signifies the opposite. Probably the closest to Properly Functioning with respect to the NMFS (1996) guideline for pre-development width/depth ratio is the least-developed, moderate gradient South Fork Skykomish River.

Table 3-11.
Summary, Width/Depth Ratio Indicator

River	*Properly Functioning*	*At Risk*	*Not Properly Functioning*
Green			X
White			X
Cedar			X
Snoqualmie			X
S. Fork Skykomish		X	

0308 BEA T3-11.eps LPRE

Streambank condition. Streambank stability is currently Not Properly Functioning at many failing bank locations within the programmatic action areas. The best-documented examples occur along the lower Green River. Many of these banks are composed of undersized riprap that was placed by end dumping in oversteepened configurations over the native bank materials, which at most locations are composed of alluvial sands and silts (King County 2001). As a result, the banks are highly prone to saturation slump failure during drawdowns following prolonged release of stored floodwaters from Howard Hanson Dam. Other streambank stability problems exist along other King County rivers, so these would probably be scored At Risk at best.

Table 3-12.
Summary, Streambank Condition Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar		X	
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-12.eps LPRE

Floodplain connectivity. Because of levees and revetments already in place, linkages of wetlands, floodplains, and riparian areas to the main channels have been reduced to varying degrees in all King County rivers. That, plus the reduction of overbank flows relative to historical levels, is sufficient for an At Risk assessment for this indicator for all but the Green River, which is Not Properly Functioning under the NMFS (1996) guideline.

The lower Green River within the programmatic action area is Not Properly Functioning in terms of floodplain connectivity (King County 2001). Logging, systematic removal of LWD, and conversion of the lower Green River floodplain first to agriculture and ultimately to residential and urban land uses have dramatically reduced secondary channels, off-channel ponds and tributary channels that formerly protected salmonids from damaging floodflows in the winter and provided cool water refugia in the warmer months. In addition, diversion of the White River narrowed the floodplain downstream of RM 31.2, forming a new floodplain within the old channel (Perkins 1993). The new floodplain is at least seven feet lower than the former floodplain (Dunne and Dietrich 1978), and many of the smaller tributaries along the lower Green River are conveyed into the river through flap gates that are perched above the OHWM. As a result, many of the remaining off-channel habitats are affectively disconnected from the river.

Levees and revetments have also eliminated much of the historic connection between the Cedar River and its floodplain. Even so, an inventory of off-channel habitats conducted by the County in 1992 revealed a network of 68 such habitats still in existence including wall-base tributaries, side channels, and riparian wetlands (King County 1993a). Of these, 59 off-channel habitats remain connected with the Cedar River; only nine are inaccessible to fish. Of the still-connected habitats, 22 of the sites are rated as outstanding in condition and are well utilized by fish. Fish production is limited in the other 37 connected sites because of impaired habitat conditions within the sites themselves (King County 1993a).

In the lower White, Snoqualmie, and a small portion of the South Fork Skykomish Rivers, overbank flows have been reduced by flood control facilities. The limited height and reduced level of protection afforded by these facilities means that at many locations the mainstem channels still connect with their floodplains under some flows.

Table 3-13.
Summary, Floodplain Connectivity Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-13.eps LPRE

Environmental Pathways and Indicators—Flow/Hydrology

Change in peak/base flows. Peak flow, base flow, and timing characteristics appear to be Properly Functioning relative to historic levels for the Snoqualmie River and may also be for the South Fork Skykomish River. All other King County rivers have been altered relative to historic levels for this indicator. The Cedar and White Rivers flows have been altered by water diversions by the City of Seattle and

Puget Sound Energy, respectively, as well as by construction and operation of Mud Mountain Dam on the White River. The Green River flows have been altered by diversion of the White and Cedar Rivers away from the Green River earlier in this century, and by construction and operation of Howard Hanson Dam. Green River water is also diverted by the City of Tacoma. The Cedar, White, and Green rivers are rated Not Properly Functioning for this indicator.

Table 3-14.
Summary, Peak/Base Flow Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar			X
Snoqualmie	X		
S. Fork Skykomish	X		

0308 BEA T3-14.eps LPRE

Drainage network increase. This indicator addresses increases to the natural drainage network of a river or stream brought about by road building or artificial drainageways such as ditches, culverts, retention/detention ponds, or stormwater pipes. All programmatic action areas along King County rivers have been affected by these anthropogenic activities to some extent. This effect ranges from the South Fork Skykomish River, which appears to be least disturbed in this regard, to the heavily developed and thus heavily disturbed Green River programmatic action area. The existing drainage network in the catchments draining to the lower Green River is Not Properly Functioning because of significant increases in artificial drainage networks related to the urban and residential development over the past several decades. Significant changes in drainage network to the Green River have occurred in the valley cities of Renton, Tukwila, Kent and Auburn (Fuerstenberg et al. 1996; King County 2001).

Table 3-15.
Summary, Drainage Network Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-15.eps LPRE

Environmental Pathways and Indicators—Watershed Conditions

Road density/location. Existing road densities in King County programmatic action areas generally range across the spectrum from greater than to less than three lineal road miles per square mile. Moreover, there are many valley bottom roadways in all of these programmatic action areas. Therefore, all of the rivers are rated Not Properly Functioning with respect to this indicator.

Table 3-16.
Summary, Road Density Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar			X
Snoqualmie			X
S. Fork Skykomish			X

0308 BEA T3-16.eps LPRE

Disturbance history. The NMFS (1996) guidelines for this indicator come directly from the Northwest Forest Plan (USDA and USDI 1994), and refer primarily to late successional old-growth forest stand integrity. This is not a useful set of criteria for the rivers and programmatic actions considered here. For our purposes, we considered the overall progression of land uses which has occurred in King County river basins over the years, from forestry to agriculture to urbanization and industrialization (see Ehrlich 1978 for a treatise on contrasting effects of these changes in the Green River valley as opposed to the Snoqualmie River valley), as well as man-built channel alterations, water diversion, and dams. Qualitatively, King County rivers were ranked in order, from least disturbed to most disturbed: South Fork Skykomish, Snoqualmie, Cedar, White, and Green.

All King County rivers have a history of disturbance such that, by application of the modified indicator criteria, would rank them At Risk at best with the Green and White (and possibly the Cedar as well) ranking as Not Properly Functioning.

Table 3-17.
Summary, Disturbance History Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White			X
Cedar			X
Snoqualmie		X	
S. Fork Skykomish		X	

0308 BEA T3-17.eps LPRE

Riparian reserves. Along most of the rivers in the King County programmatic action area, riparian reserves have been fragmented to a degree that would rank them At Risk or Not Properly Functioning by the NMFS (1996) guideline. Along the Green River, for example, the existing riparian reserve system is Not Properly Functioning because it is much less than 70 percent intact (Fuerstenberg et al. 1996; King County 2001). Over 80 percent of the banks of the lower river have undergone significant removal of riparian vegetation during conversion of riparian lands to agricultural, residential and industrial uses that currently preclude restoration of riparian forests. Many project sites lack significant stands of riparian vegetation because of trails, roadways, commercial and residential buildings, flood control facility maintenance roads, and, in two cases, golf courses, were constructed immediately adjacent to the top of bank. In others, the presence of non-native invasive plants such as reed canarygrass, knotweed, Scot's broom and blackberries in monocultural or bicultural stands inhibits successional processes that would otherwise lead to reestablishment of riparian forests. Long stretches of the Green River show little or no natural re-colonization by native species, even though no wholesale vegetation removal has occurred in some areas for over forty years.

Along the Cedar River, where riparian corridors are less fragmented, approximately 56 percent of the basin downstream of Landsburg is forested. However, the present Cedar River riparian reserves are dominated by deciduous trees with only about 37 percent of the forested tracts in conifer stands. Most of these stands are less than 55 years old (King County 1993a). Stands of conifer less than 55 years old generally do not provide significant recruitment of LWD to stream channels (Grette 1985; Franklin 1992). The generally immature condition and deciduous dominance of Cedar River riparian corridors means that many of their habitat functions and values are reduced from Properly Functioning condition.

No current data on riparian reserves along the other King County rivers were identified. The Snoqualmie River is rated Not Properly Functioning because of the general lack of large woody vegetation along its length. The White and South Fork Skykomish Rivers have more large woody vegetation along their lengths, and thus, were placed in the At Risk category.

Table 3-18.
Summary, Riparian Reserves Indicator

River	Properly Functioning	At Risk	Not Properly Functioning
Green			X
White		X	
Cedar			X
Snoqualmie			X
S. Fork Skykomish		X	

0308 BEA T3-18.eps LPRE

SUMMARY

Table 3-19 summarizes the environmental baseline of the rivers in the King County River Management Program river corridor areas using the *Matrix of Pathways and Indicators*.

Table 3-19. Matrix of Pathways and Indicators - Environmental Baseline Condition

PATHWAYS AND INDICATORS	ENVIRONMENTAL BASELINE		
	Properly Functioning	At Risk	Not Properly Functioning
WATER QUALITY:			
Temperature	S. Fork Skykomish	Cedar River Snoqualmie River	Green River White River
Sediment/Turbidity		Green River White River Cedar River Snoqualmie River S. Fork Skykomish	
Chemical Contaminants/ Nutrients		White River Green River Cedar River Snoqualmie River S. Fork Skykomish	
HABITAT ACCESS:			
Physical Barriers		S. Fork Skykomish	Green River White River Cedar River Snoqualmie River
HABITAT ELEMENTS:			
Substrate	Snoqualmie River S. Fork Skykomish	White River Cedar River	Green River
Large Woody Debris		White River S. Fork Skykomish	Green River Cedar River Snoqualmie River
Pool Frequency		White River Snoqualmie River S. Fork Skykomish	Green River Cedar River
Pool Quality		White River Snoqualmie River S. Fork Skykomish	Green River Cedar River
Off-channel Habitat		S. Fork Skykomish	Green River White River Cedar River Snoqualmie River
Refugia		White River Snoqualmie River S. Fork Skykomish	Green River Cedar River
CHANNEL CONDITIONS & DYNAMICS			
Width/Depth Ratio		S. Fork. Skykomish	Green River White River Cedar River Snoqualmie River
Streambank Conditions		Cedar River White River Snoqualmie River S. Fork Skykomish	Green River
Floodplain Connectivity		White River Snoqualmie River S. Fork Skykomish	Green River Cedar River

0308 BEA T3-19p1.eps LPRE

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Table 3-19. Matrix of Pathways and Indicators - Environmental Baseline Condition *(Cntd.)*

PATHWAYS AND INDICATORS	ENVIRONMENTAL BASELINE		
	Properly Functioning	At Risk	Not Properly Functioning
FLOW/HYDROLOGY:			
Peak/Base Flows	Snoqualmie River S. Fork Skykomish		Green River White River Cedar River
Drainage Network Increase		White River Snoqualmie River S. Fork Skykomish	Green River Cedar River
WATERSHED CONDITIONS:			
Road Density/Location			Green River White River Cedar River Snoqualmie River S. Fork Skykomish
Disturbance History		Snoqualmie River S. Fork Skykomish	Green River White River Cedar River
Riparian Reserves		White River S. Fork Skykomish	Green River Cedar River Snoqualmie River

0308 BEA T3-19p2.eps LPRE